HIGH INTENSITY HEAVY ION BEAMS FOR EXOTIC NUCLEI PRODUCTION AT GANIL

E. Baron, Ch. Barué, J.L. Baelde, C. Berthe, D. Bibet, F. Chautard,
C. Jamet, P. Gudewicz, P. Lehérissier, F. Loyer, M-H. Moscatello,
E. Petit, A. Savalle and G. Sénécal
GANIL, BP 55027 - F14076 Caen Cedex 5 , France

Abstract

The GANIL heavy ion accelerator can be used as a driver for producing exotic beams either by fragmentation of the projectile, or by the ISOL method through the SPIRAL complex. The accelerator was first equipped with several devices for protection against thermal effects and activation. Then tests were carried out to increase the primary beam intensities, especially for projectiles ranging from C to Ar. The goal of $2x10^{13}$ pps was obtained with a 75 MeV/n carbon beam extracted from SSC2 for several hours. Losses at extraction limited the Ar intensity to $5x10^{12}$ pps, while a $1x10^{13}$ pps was aimed at. For some other ion species, substantial increases were obtained, although their use are somewhat limited by weaknesses in the concrete shielding. Detailed results of these tests are discussed. Possible cures to overcome limitations are presented, along with results of simulations concerning the effect of longitudinal space charge forces.

1 INTRODUCTION

The production of exotic nuclei at GANIL is presently performed by fragmentation of the projectile in the target of SISSI [1]; it will be soon completed by the ISOL method, with subsequent acceleration of the rare isotope beams by the cyclotron CIME [2]. Both devices require high intensity primary beams. The THI project, described in details in the proceeding of the International Conferences on Cyclotrons [2,3], consists of a series of actions undertaken on the GANIL accelerators components in view of increasing the present intensities of light ion beams (up to atomic numbers $Z \approx 20$). The aim is to go from 400 watts, which is considered as a safe value for the beam power if no special precaution is taken, up to a maximum value of 6 kW, a limit imposed both by the thermal properties of the targets and the need for a "reasonable " amount of additional shielding. Examples of goal figures are given in table 1.

Table 1. The power is given for 95 MeV/n beams.

Projectile	Present intensity(pps) for 400 watts	Expected intensity (pps)	Beam power (kW)
^{12}C	2.2×10^{12}	2×10^{13}	3.7
^{16}O	1.6×10^{12}	2×10^{13}	4.9
^{20}Ne	1.3×10^{12}	2×10^{13}	6.1
^{36}Ar	7.3×10^{11}	1.1×10^{13}	6.0

The series of adaptations required by this upgrading in terms of protection of the components and control of the beam behavior is described below, along with the results of the beam tests and the proposed strategy to overcome some limitations.

2 THE ACCELERATOR IMPLEMENTATION

2.1 Ion source and platform

For the ion species obtained from gaseous elements, the GANIL ECR4 ion source delivers enough intensity to reach the output goals, provided beam losses are minimized in the cyclotrons and beam lines. However, efforts are to be spent in order to get stability over days, especially when the total current drained from the source brings an excessive loading of the 90 kV accelerating tube of the insulated platform. As for ions from condensable materials, developments are worked on, especially through the MIVOC and oven methods, and beams of ^{58}Ni (800 W) and ^{36}S (1 kW) have been already used by the experimenters.

2.2 Improving transmission and protection

A series of actions described elsewhere [3,4] were undertaken to adapt the facility to a high intensity situation. We shortly recall the most important aspects:

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Table 2. Important adaptations.

Element	Additional equipment	Active use
Beamline dipole vacuum chambers	Thermal shields (C ,W, w-cooled)	
Idem, entrance & exit	carbon collimator	triggers intensity reduction if loss by defocusing or misalignment [5]
SSC1,intermediate beamline, SSC2	Differential current transformer	Idem
Front-ends of inj-extraction devices	Copper electrodes	Idem + help for beam tuning
Beamline upstream from SSC2	200 kV buncher	reduces turn width at extraction
Carbon foil stripper	Slow d.c. or step-by-step rotation	increases foil lifetime
SSC2 electrostatic deflector	Front-end collimator reinforced	
Power supplies	Double supervision	Fast identification of the trip origin
Injection-extraction devices	Thermistors in inner channel	Localize permanent internal losses

3 TUNING METHOD

Several methods are possible to step-by-step tune the accelerator for high intensity, while protecting the secondary emission beam profile monitors (when they are in the beam, the average intensity has to be reduced by a factor of 500) and other fragile elements. A combination of pepper-pot and chopper was chosen. The beam is tuned at low intensity with these two devices and, once the BPMs are removed, the pepper-pot is also removed and the intensity is step by step increased by varying the repetition rate of the chopper.

This combination is not quite satisfactory, particularly because the tuning is sensitive to the peak intensity: a new chopper has to be designed so as to avoid using the pepper-pot. As discussed below, this is due to space charge forces.

4 RESULTS AND PERSPECTIVES

4.1 Beam tests and routine operation

The first test beam was $^{36}Ar^{10+/18+}$ accelerated at 95 MeV/u. The intensity extracted from the ion source at 85 kV and in a 60 x 60 π mm mrad emittance is of the order of $5x10^{13}$ pps, which should be sufficient to reach $1.1x10^{13}$ pps at SSC2 output, corresponding to a power of 6 kW. The tests led to the following results:

1) A 2 kW ($3.6x10^{12}$ pps) beam could be extracted from SSC2 and maintained for more than 30 hours. It is indeed important to carry a constant heat load inside the production target of SPIRAL in order to maintain its temperature as constant as possible
2) In spite of several attempts, the goal of a 6 kW ($1x10^{13}$ pps) extracted beam could not be reached, some limit standing in the vicinity of 3 kW (figure 1). The most important limiting factor is the amount of beam lost in SSC2 and in particular in the extraction process.

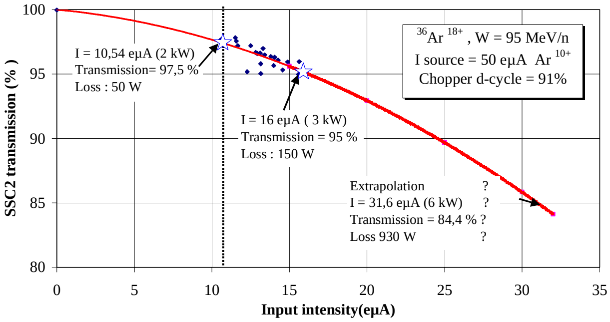

Figure 1. SSC2 transmission efficiency versus input intensity for an argon beam.

A second test was performed with a $^{13}C^{3+/6+}$ at 75 MeV/n. In a first 13 hours period, a $1.3x10^{13}$ pps (2kW) beam was extracted from SSC2 (figure 2).

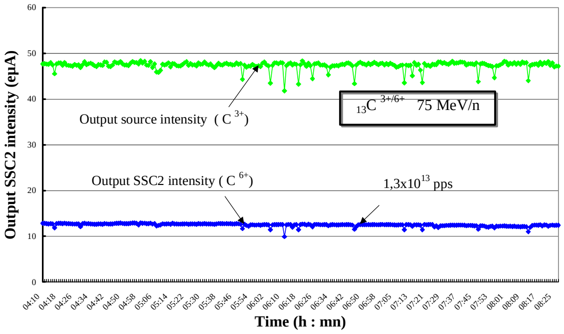

Figure 2. Source and SSC2 output intensities versus time for the carbon beam

Then, the ultimate goal of $2x10^{13}$ pps (3 kW) was reached and sustained for several hours.

A test with a 95 MeV/n , ^{20}Ne $^{6+/10+}$ revealed that a beam intensity augmentation above 3 kW at extraction of SSC2 led to too high losses. It was definitely shown that is due to longitudinal space charge forces and related to the large number of turns in SSC2.

As mentioned in 2.1., beams of ^{58}Ni (800 W) and ^{36}S (1 kW) are considered now as routine operation.

4.2 Analysis of the limitations and search for improvements

In the cases mentioned above, it was difficult to go beyond a 95 % transmission efficiency through SSC2 with ≈ 1×10^{13} pps intensities, with the consequence of a loss in the extraction system. As indicated by Th. Stammbach [6], longitudinal space charge forces are to be suspected in this SSC, where the bunch length reaches 15 to 20 cm : while the separation between the last two turns may be of the order of 1 cm, the bunch tilt (and/or its tails) makes its apparent radial width larger than this value. Computer simulations as well as beam tests substantiate this idea of a deterioration of the beam qualities (like a widening of the turn at extraction). In order to find a way to overcome this limitation, these simulations are currently pursued and have been extended to the injector cyclotron, where part of the origin of the phenomenon may also lie [7].

In the meantime, a watercooled shield capable of withstanding a 600 W power was installed upstream from the electrostatic deflector of SSC2, then allowing up to a 10 % loss if no other cure were found.

Other improvements are underway. They deal in particular with correcting the instabilities of the beam and of the beam diagnostics :

- the instabilities of the (low frequency) differential current transformers trigger the safety interlock system too frequently because they are too noise-sensitive. A new type of current transformer operating at the cyclotron RF frequency has been developed and should cure the problem.
- a new chopper, capable of reducing the intensity by a factor as low as 500 must be developed in order to suppress the obligation to operate a first tuning of the cyclotrons with a pepper-pot which deeply modifies the space charge effects.
- a complete modification of the ion source platform is under study : in order to minimize the accelerating tube load, a charge state selection will be installed between the source and this tube.

4 NEAR FUTURE

As soon as the administrative authorizations are delivered by the Safety Authorities, beam tests of line L4 linking the α spectrometer to the production target of SPIRAL will be undertaken, first at low intensity to check all the alignment, focusing and wobbling functions, along with the beam loss detection system. Then, a 2 kW, 95 MeV/n $_{20}$Ne beam test will be reiterated, followed by the full-scale test on the target and subsequent production and acceleration of ^{18}Ne.

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